OXC - 4051
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MEMORANDUM FOR THE RECORD

SUBJECT : Status Report and Evaluation of OXCART Camera Systems and Accessories

I. <u>Perkin Elmer Type I A</u>

A. Design Philosophy

1. Given a known altitude and airspeed with estimated environments of vibration, temperature, roll, pitch and yaw instabilities, to design and build a photographic system that would produce the ultimate in angular resolution, compatible with the installation space available, the effective range of the carrying vehicle and the lateral coverage requirements for stereoscopic photography.

2. Ideally, such a system would require:

a. An optically transparent homogeneous atmosphere between the camera and the earth, free of dust, moisture, temperature variations, and of uniform density.

b. A lens of a focal length equal to one half the altitude having an entrance pupil that would give horizon to horizon coverage without distortion.

c. The camera platform should be oriented perpendicular to a line passing through the center of the earth with the direction of flight passing through the center of the format.

d. Since the taking vehicle is moving with respect to the object being photographed, the effective shutter speed should be fast enough to record the image before any measurable movement of image occurs.

e. The film should have a light sensitivity or speed sufficient to record the image during the time that the shutter is open.

f. The light sensitive particles in the film should ideally be no more than one wave length of light deep and one wave length in diameter in order to ensure the ultimate in angular resolution.

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g. Other factors which contribute to the degradation of the final image include:

(1) Boundary layer turbulence outside the aircraft (density variation).

(2) Thermal gradients between the ground and the film (atmosphere, windows in the aircraft, lens elements, mirror surfaces and the space between the lens and the window as well as the structure of the camera itself).

(3) Distortions caused by projecting a curved surface (the earth) on to a plane surface (focal plane).

(4) Angular movements in the roll, pitch and yaw during the time that the image on the film is being formed.

(5) Vibration of varying frequencies and amplitudes in the x y and z axes as well as harmonics and vectors of each.

(6) Altitude and ground speed variations.

(7) Atmospheric scatter.

(8) Atmospheric refraction.

(9) Sun angle.

(10) Aberrations (chromatic, spherical, coma, and astigmatism).

(11) Dispersion caused by the variation in wave length of the constituent colors that make up white light.

3. Obviously, the laws of physics make the ideal system impossible to achieve. The state of the art in physical optics, emulsion technology, environmental control, and film transport systems limit the design of the system.

4. Perkin-Elmer approached the problem by:

a. Exploring the effects over which they had no control in order to determine their quantitative effect.

b. Exploring the performance characteristics required to make the system of high enough quality that degradation caused by controllable factors would contribute equally.

c. Selecting a focal length as a compromise between resolution (300 lines/mm high contrast) speed required using a film that is available and the weight space limitation in the carrying vehicle.

d. Limiting the effect of motions between the film and the photographic image through isolation of the camera from the vibration in the carrying vehicle.

e. Compensation for image movement due to the foreward motion of the vehicle.

f. Synchronising the film movement with the image movement in the focal plane.

g. Compensating for the angular movement of the vehicle in roll, pitch and yaw by use of a so called stable platform.

h. Avoiding or damping internal camera vibrations.

i. Employing a film transport system that permits a motion of the film in a direction perpendicular to its normal travel in order to apply the proper V/H (velocity over altitude, the factor that controls rate of film travel for correct overlap of successive exposures). Since the film must slide along the supporting roller at the same time it rolls over it, a pneumatic support was developed in which the film contacts nothing but itself as it passes through the camera.

j. Developing a double plate window for the optical system to look through that has a hard vacuum between the two plates. The purpose of the vacuum window is to limit the degrading effects of high temperatures from the outside of the aircraft on the optical system and to reduce the effect of thermal turbulence between the lens and the outside of the aircraft.

k. Using the field angle of their optical system only in one direction and employing a slit at the focal plane for recording the image giving a diffraction limited lens across the full aperture.

5. Each of these approaches was examined in great detail with a view of selecting the single method out of several possibilities that would afford the greatest return in resolution, coverage, focal length and range.

B. Evaluation

1. This philosophy led the contractor into the position of accepting unnecessary mechanical and electrical complexities in exchange for minute performance improvements. The resulting camera requires extremely critical mechanical, optical electrical and electronic adjustments to achieve top performance. It requires careful environmental control (helium atmosphere at one third sea level pressure). It will require external vacuum pumps or ion exchangers to maintain the vacuum window. It takes about eight hours to thread the film through the transport. The V/H is voltage and frequency sensitive. Dust and dirt constitute a major hazard not only to the film but to the camera mechanism as well.

2. The initial test flight conducted in a C-123 aircraft at Norwalk, Connecticut produced surprisingly good results, considering the circumstances under which it was accomplished.

The camera was loaded and ready then held on the ground by rain for 54 hours before the test.

The aft lens was misaligned.

The scanner drive was not within specification.

The roll and pitch stabilizer had a bad bearing.

The slits were dirty.

The capping shutter had a phasing error.

The V/H sensor was inoperative.

The forward unit flash for the data chamber was inoperative.

3. A test flight conducted on 12 October gave satisfactory performance of all subsystems through a five hour mission exposing 4000 feet of film.

4. The over-all system, although quite complex, balances the contributing degradations of film, lens, stabilization IMC, vibration and windows to the extent the cumulative distortions will permit ground

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resolution of one foot at 80,000 feet altitude.

C. Status

1. The Type I A system has completed its test flights in the
25X1 C-123 and will be moved to [redacted] during the week ending 20 October.

2. Vibration tests and system check out will be conducted in the number two aircraft followed by flight tests at reduced altitude and airspeed in the number three aircraft. Flight tests at rated performance are scheduled through the third week in February.

3. Type I B is almost identical with Type I A. The primary optics are not quite as good in the first unit but the mirrors are slightly better. This system will be completely assembled and ready for in-house test by 1 January. Flight tests are scheduled from 1 March through June.

4. System I C will incorporate improvements indicated by full system area tests of Type I A with particular reference to V/H sub-system - automatic lock on, shuttle structure, optical bench and platform isolators natural frequency. Flight tests of this system are scheduled for August 1963. The contractor has been authorized to proceed with the lens for the fourth system.

II. Eastman Kodak Type II A

A. Design Philosophy

1. To construct a camera having high reliability, wide angular coverage, as long a focal length as possible within the restrictions of weight, installation space and mechanical considerations. State of the art techniques were employed throughout so that time consuming research and development efforts did not interfere with the delivery schedule. A balanced system was developed in which no one component was outstandingly superior to other components. The simplest system concepts that would produce the desired ground resolution of 1 1/4 feet were employed.

B. Evaluation

1. Since the principle effort on the initial unit was placed on completing the system in a short time and getting flight tests accomplished from which engineering data could be obtained for improving the second package, it is not valid to assume that the results of these tests are typical. However, the system did demonstrate good reliability in a series of eighteen flight tests in which only 250 exposures were lost due to

malfunction out of 102,470 taken. The ground resolution demonstrated in these tests was on the order of 1 1/2 to 2 feet from an altitude of 65 to 70,000 feet. These tests, conducted in the U-2 aircraft, at a much slower speed and a different thermal environment, are not necessarily representative of the kind of results that may be expected from the OXCART. As may be seen in Table I, the 21" f/4 lens provides a slightly larger scale than the 18" f/3.8 of Perkin-Elmer, although it is somewhat less efficient at light gathering. The width of coverage is about seven miles less than the Perkin-Elmer camera, but it covers about 64,400 square miles more during a mission due to the 8400 feet of film employed as against Perkin-Elmer's 5000 feet.

C. Status

1. Flight tests of the flying breadboard model have been completed in the U-2 and the package has been converted to Type II A for installation in the A-12. Tests in the number three vehicle will be conducted in October and November. Type II B is scheduled for shipment
25X1 [redacted] for test January 31, 1963. Type II C is scheduled for shipment May 31, 1963.

25X1 2. The [redacted] subcontract for a V/H system is due for delivery to Eastman Kodak on 25 January 1963 and will be going into field tests 1 February 1963. This backup system is the heart of the control mechanism for both the Eastman and the Perkin-Elmer systems. It was ordered to ensure a useable equipment in the event that the Perkin-Elmer V/H was not successful.

III. Dynametrics Type III A

A. Design Philosophy

1. To convert a "B" type camera to a configuration that could be used in the OXCART vehicle at the altitudes, airspeeds and environmental conditions required. Originally it was intended that two such conversions would be undertaken; however, the shortage of "B" cameras and the apparent success of the Type I and Type II systems made this unnecessary.

2. The modifications accomplished included only those necessary to adapt the unit to the new vehicle thus preserving the demonstrated reliability of the "B" camera. Thermal effects on film, focus and windows were considered. A new programmer was built and a change was made in the IMC to accommodate the 1 1/4 second indexing time.

3. A live window hatch was built employing vacuum windows. The camera bay is pressurized at 5 psi.

B. Evaluation

1. The 36" f/10 lens delivers 55 lines/mm on axis at 25% contrast. It is expected that 50% of the photos will have better than 30 lines/mm or a ground resolution of 3 to 4 feet. This system has the advantage of a longer focal length but the slow speed lens f/10 makes it incapable of using the higher resolution film SO-132 which has an exposure index of only 1.6 compared to 64 of the faster but grainier 0-11-3402 currently being used.

2. This limitation is serious in view of the higher speed aircraft.

3. The necessity for rapidly moving the camera from one window position to the next and indexing it requires particular attention to smoothness of operation and vibration damping.

4. The physical limitation imposed by the new environment indicate that ground resolution will be on the order of 20% less than the standard "B" camera in the U-2.

C. Status

25X1

1. Flight tests of the Type III camera are currently being undertaken at [redacted] During the early flight test phase it was learned that the lens contained radial and tangential distortion. A substitute lens was provided for the flight test program and the bad lens returned to Perkin-Elmer for rework.

IV. <u>Accessory Equipment for OXCART</u>

1. Astro Compass and Map Projector

A mock-up of the map projector and astro compass has been completed and was examined for design approval by the writer and [redacted] on 17 October at Cambridge, Massachusetts. Essentially this unit consists of a periscope that permits either viewing of the ground or viewing a projected map of the flight path.

25X1

2. Map Destruct System

a. Water soluble paper in 42" x 58" sheets, quantity 500, has been ordered and delivered to ACIC for map production.

b. A map case has been built by Lockheed and delivered here for suitability tests using the water soluble paper. The system employs a valved water inlet from a tank in back of the driver, that upon command will fill the map case with water and destroy the maps.

3. Tape Recorder

TSD has provided one terminal set of an experimental pocket tape recorder that includes two units. One will be sent to Lockheed or Edwards AFB for field evaluation and one will be sent to CBS for rework. The rework involves a destruct system, a G switch and a remote momentary "On" switch.

4. Airborne Mission Data Recorder

All interfaces between Perkin-Elmer, Eastman Kodak and Minneapolis-Honeywell have been resolved. M-H is building the engineering model. NPIC is satisfied that the data they will receive will meet their programming needs. Unresolved is whether or not M-H is producing the punched paper tape reproducer and verifier.

V. Other Areas Of Interest

A. Non-silver Photographic Materials

25X1 1. [redacted] are producing under a WADC contract, a contact printing speed material for use in the 3500 to 4000 angstrom range and a projection printing material with panchromatic sensitivity in the 3500 to 7000 angstrom range, both materials have resolution capabilities of 500 to 1000 lines/mm. The image is visible immediately and is fixed by passing it through a 100°C environment. Several advantages are evident in this type of photopolymerization process: (a) Higher resolution in taking material; (b) higher resolution in reproduction of negatives, positives or prints; (c) dry processing (no chemical solutions or at most a single monobath); (d) color positives for photographic interpretation. The single apparent drawback is lack of
25X1 speed although [redacted] is confident that speeds of ASA 2 or 3 can be achieved.

B. Lasers (Light amplification by stimulated emission of radiation)

1. A recent presentation by [redacted] on this subject indicated a level of capability in several areas that are of interest to our space and airborne reconnaissance efforts.

2. Indications are that with present demonstrable equipment a V/H sensor and a vertical reference sensor can be produced giving better

performance than equipment that is currently being employed.

3. In a discussion with [redacted] program coordinator of [redacted] on 5 October, I asked him to specifically inquire of his experts what accuracies they could guarantee for shaft angle measurement in roll, pitch and yaw as well as real time accuracies for navigation use. A recent call from [redacted] informs us that they have worked on the problem and will be ready to talk after 1 November. 25X1 25X1 25X1

[redacted] 25X1

C. Mirror Optics

1. [redacted] Long Island, New York, has two systems of interest. 25X1

a. A [redacted] concentric mirror meniscus system with a cone lens that gives a large field, high resolution, long focal length, and light weight. I asked about a 100" focal length, 50 lines/mm resolution, 9 x 9 format, 20° angle at 3' or less length and 40 pounds of weight. They will come back with their approach. 25X1

[redacted] 25X1
Development Division
OSA-DD/R

Distribution:
1-DD/OSA
2-DD/OSA
3-OD/OSA
4-SD/OSA
5-CD/OSA
6-C/DD/OSA
7-RS/OSA
8-DD (Chrono)
DD/OSA/RLT:rel